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THE LONG LEAF PINE AND ITS STRUGGLE FOR EXISTENCE.

BY W. W. ASHE.

As a country increases in population the relative area of its woodland and forests, from which both timber and a large part of its fuel must be drawn, decreases in like or even greater proportion. The care and propagation of timber trees *en masse* becomes a feature of economic administration; and in all cases the inauguration of the policy of forest cultivation has emanated from the government. The cause of this dependence on the government for the initiation is patent. Although individuals may see, as forest materials become scarcer, that some definite plan, in regard to forest management, should be followed, they are, as a body, unable to put on foot a general line of action which will in any measure tend to increase the supply.

This inaction of individuals is due to two causes: (1) A disregard for the future, since the benefit of any reform, or at least the realization of increased income from any reform which may be made in the management of forests will be derived only after many years; broadly speaking will be of advantage only after the

passing of a generation. For this same reason there is an increasing tendency to cut all marketable trees, even of the smallest size, that returns may be had at once.

(2) Even when some desire is evinced to so care for woodland that the return therefrom may be regular and the condition of the woodland may not deteriorate, either in respect to average size or choice of trees, there is great ignorance shown of all requirements for tree growth and of the action demanded to secure desired results.

The larger and more thickly settled European governments, recognizing these facts, have many years ago undertaken to place all their own forest lands under systematic management and at the same time supply, by means of their schools of forestry, the knowledge of these methods to private land-holders or to trained officers who may serve them. In many of these schools series of experiments, analogous to those made upon grains, etc., in the Agricultural Experiment Stations of the United States, have been carried on upon forest trees, to determine the conditions of light, soil, moisture and density of tree growth which they require for their best development, and the age they should be allowed to reach before cutting, the diseases, fungous and other, to which they are subject, their destructive insects, and the trees, naturally and those most advantageously, associated together in forests.

What has been done by these governments for their forests will have to be repeated in modified forms by the federal and various state governments for their respective forests as soon as the great bodies of standing timber which have required the uninterrupted efforts of centuries to accumulate, are destroyed or thinned

out. Conditions will be presented analogous to those experienced in Europe and these must be treated along the same lines and finally resolved by the application of similar methods and by considering the general effects upon our trees of their environments, the soils, atmospheric changes and the various forms of plant and animal life. It will be understood from this how necessary it is that the pathological characteristics of trees worthy of extensive culture for their timber, should be known.

As yet we are in the dark about the demands of even our more common trees. As a people it has scarcely become known to us that our forests are exhaustable, much less that there are large waste areas, now entirely unproductive of commercial timbers and that these areas less than fifty years ago were wooded, in some instances heavily wooded, with valuable trees. There are such tracts of waste land in North Carolina in what are known as the "pine barrens" of the eastern counties. In the course of an examination of the timber lands of eastern North Carolina undertaken last year (1893) by the North Carolina Geological Survey some inquiry and research was made into the extent of these waste areas and a more extended discussion of the results of this examination will be found in Bulletin 3, of the North Carolina Geological Survey, now being published. These areas were found to include considerably over 400,000 acres and to be increasing so rapidly that the causes leading to them were sought for. This entailed an analysis of the life history of the long leaf pine and of the other pines with which, in this region of North Carolina, it is most intimately associated. While these observations are by no means either exhaustive, or even full, they will show in a general way

with what difficulties a tree has to struggle, under the changed condition of civilization, in order to grow up and reach maturity. They also show the pressing need for a more efficient, or at least common sense, method of dealing with our forest lands if there are in the future to be any forests.

A brief statement of the facts noted in regard to these pine lands, summarized from the same bulletin, will serve to show the deplorable condition of these lands at the present time and how they were when covered with virgin forests.

There are four pines found in the eastern section of North Carolina. Only two of these are, however, generally enough distributed to be of economic importance. These are *Pinus palustris* (Miller) the long leaf pine and *Pinus taeda* (Linné) the loblolly pine, called in eastern North Carolina short leaf or old field pine. The loblolly pine has numerous close allies in eastern America and Europe, though it is a very distinct tree from any of these. Its growth in the virgin forest is confined to the wet margins of the swamps, to "hammocks" in the swamps and to the moister lands with sand or loamy soils, even when sometimes immersed.

The long leaf pine has in North Carolina reached the farthest northerly extension of any pine in its subsection of the genus Pinus. Taking the sum of like morphological characters as expressing the greatest relationship and starting with the white pines, which are the most northerly distributed pines of America, it will be found that the sub-section of the genus Pinus, to which the long leaf pine belongs, is farthest from the white pines, *i. e*, has fewer like characters in common, and at the same time has the most southerly extension of any pines of America. The congenitor of

the long leaf pine is the Cuban pine, *Pinus cubensis* (Goert) which is found in Florida, Georgia, and the West Indies, while other nearly allied species are found in Mexico and the tropics.

Byrd, Lawson,* and the other early historians and eulogizers of eastern North Carolina unanimously assert that the long leaf pine extended over all the higher sandy land from Nansemond county, Virginia, southward. It was abundant in Hertford, Perquimans and Gates counties, where a tree of this species is rarely ever seen now, and through Bertie county which was then called the "Pine Forest" and which is now covered with a heavy growth of loblolly pine. Long leaf pines must have been common in the Pamlico peninsular as tar kiln mounds, now covered with large trees of other species, are frequently seen as one rides along the road. Within the last fifty years the upland forests of Wilson, Edgecombe and the northern section of Wayne counties were composed almost entirely of long leaf pine, while at the present time the loblolly pine has gotten possession of this land wherever the soil was sufficiently moist to support the growth. South of the Neuse river over the rolling dry sandy soil of the "pine barrens" the long leaf pine held undisputed possession. These lands are two poor and dry for the loblolly pine to grow upon until the soil has been cultivated and fertilized. The only tree which disputed the control of these lands, with the long leaf pine, was a small oak, the sand black jack oak, *Quercus catesbæi* (Michx) which is worthless for all timber purposes. As the long leaf pine after having been worked for turpentine was burnt off of these tracts or was cut for

* Byrd writing in 1728. Lawson in 1701.

lumber, the only tree which replaces it was this sand black jack oak.

These waste tracts, either naked or covered with the sand black jack oak, lie south of the Neuse river and are to be found in every county from New Hanover westward to Richmond and Moore. It was with a view to ascertain the feasibility of restocking these lands with a valuable tree and preventing the enlargement of these waste acres that this examination was made of the habits, characteristics and relative adaptability to existing conditions, both natural and artificial, of these two pines, *Pinus taeda* and *P. palustris*.

THE CAUSE OF THESE WASTE LANDS.

From the preceding it appears that there is a large amount of waste land lying in the southeastern part of this State. There are now over 400,000 acres of such land, and the amount of it, from various causes, is constantly increasing. This land consists of high rolling or hilly sand barrens, formerly covered with extensive forests of long leaf pine. These forests yielded turpentine abundantly, but on account of the larger amount of sapwood and the coarser grain of the wood of trees growing on these poorer sandy lands the lumber, though of good quality, was of a grade inferior to that from trees grown on fertile soils. Now, however, owing to the grossest neglect, large portions of these forests have either been destroyed entirely or reduced to such a condition that there is neither mill nor turpentine timber on them, and no regrowth of the long leaf pine has been allowed to take the place of the older trees as the latter were being gradually exterminated. The soils of the barrens on account of their

sandiness and poor quality will produce very few kinds of trees which have any economic importance. No valuable broad leaved trees (oaks, etc.) thrive on these lands, and among the conifers (pines, etc.) the long leaf pine is the only one growing naturally on them. The short leaf pine, where the loam sub-soil lies near the surface, is rarely found, and it is only after the ground has been cultivated and enriched and the moister layers of earth have been brought to the surface that the loblolly pine will grow there. So it seems that the long leaf pine is the only native tree of much value which flourishes on these barren sandy lands. There are very few, if any other, forests in the eastern United States so peculiarly limited as to the variety of valuable tree growth as the long leaf pine forest, particularly when it grows on the sand barrens, and there are no other forests which demand such care to obtain a regrowth of the original dominant species. Many kinds of trees after being lumbered or burnt out are succeeded by smaller and less valued species, but the original growth in time again takes possession of the land. This is the case with the spruce forests of western North Carolina, and the white cedar (juniper) in the eastern section of the State. However it may have been primarily in the long leaf pine forests, this is not the result under the present management of these pineries. After the removal of the pine the land quickly becomes waste land, and passes from a growth of sand black jack to utter barrenness. No where is there any general sign of either the long leaf or any other pine again forming a prominent part of the growth on these sand hills.

Unless there is some radical change in their management, these lands may even cease to produce the few

sand black jack oaks which now flourish on them. There is even a possibility and in fact it can be said a great likelihood that this valuable tree, the long leaf pine, will become extinct in North Carolina unless some steps are taken to secure its more general propagation. It has already become extinct over large tracts lying to the north of the Neuse river which were formerly occupied either exclusively by this pine or by mixed forests of it and hard woods and loblolly pine.

THE REASON WHY LONG LEAF PINE FORESTS ARE NOT SELF PROPAGATING.

The causes which have operated to prevent the long leaf pine from propagating itself are several, and all of them are important and act uniformly throughout this sandy area. A brief statement of some of the peculiarities of this tree may enable us to see more clearly why it needs more special protection than must necessarily be accorded other trees to enable the forests to reproduce themselves. The chief causes which have influenced and tended to retard the general regrowth of this tree at the present time arise from a highly specialized form of seed and plant structure and a decidedly unique manner of growth when compared with the other pines of this same region. These characteristic peculiarities lie chiefly in the young pine seedling, in the seed, and the structure of the leaf buds.

THE SEEDING OF THE LONG LEAF PINE.

Although the writer has not yet carried on systematic observations, on (1) the frequency of seeding of the long leaf, (2) the relative abundance of its seed as com-

pared with those of other pines, and (3) the fertility of boxed and unboxed trees of the same species, long enough to have obtained accurate results, yet the observations of different persons, thoroughly familiar, for many years, with the pine of the barrens, will, he thinks, for most of these cases be found sufficiently accurate, their results being supplemented by his conclusions drawn from a personal investigation extending over several years. Although there were certain years in a virgin long leaf pine forest, just as there are with all other trees, when there was no seed borne, yet these were rare and the yield of seed was usually abundant. Wm. Byrd, writing in 1728, says:* the mast of this tree is very much esteemed for fattening hogs through all of Albemarle County, (North Eastern North Carolina) on account of its greater abundance and the greater certainty of its occurrence (than that of the oaks). The forests of which he was speaking were largely virgin at that date. There are to be found frequent statements mentioning the same fact by other historians, of both an earlier and later date.

So far as could be ascertained the masts (as the seeds of this pine are called) have not been as abundant for the past fifty years as they formerly were. There seems to have been only three large long leaf pine masts since 1845. One of these occurred just about that time, the next one was in 1872 and there was one in 1892, which was not as large, however, as either of the preceding. There is a fairly abundant mast about every four or five years, and on intermediate years the production is small and localized. In North Carolina most of the trees which now bear seed are boxed and have been in this condition for from 50 to 100 years,

* History of the dividing line between Virginia and North Carolina, p. 29.

and the opinion prevails throughout the pine barrens that pine masts are less frequent and less abundant now than before the pines were so largely boxed and thinned out. The removal of a great part of the trees may explain, in part or wholly, why masts are less abundant. It would naturally be inferred that there would be a large decrease in the productiveness of boxed trees, whose vitality, measured by the rate of accretion between them and unboxed trees, has been greatly impaired by the practiced manner of boxing. However, from a tabulated record of observations carried on during several years, there as yet appears no marked difference between the productiveness of boxed and unboxed trees, similarly situated.

There are several important differences between the reproductive capacities of the loblolly and long leaf pines, all of them to the advantage of the loblolly pine.

The fertility of the long leaf pine is much less than that of the loblolly pine, its most frequent associate. The loblolly pine bears cones at an earlier age, and usually produces more seed, both perfect and imperfect ones, and the great variety of soil, on which the loblolly pines grow, causes a slight difference in the time of flowering of different trees, making this pine less liable to have the entire prospect of a seed yield dstroyed by frosts or by heavy rains during polination. While this may possibly explain why the loblolly pine has come up as a regrowth over so much of the moister loam land, it has affected the growth of the pine barrens very little.

The seed of the long leaf pine are very large, $\frac{1}{3}$ to $\frac{1}{2}$ an inch long, independent of the wing, while no other pine of this region has seed over $\frac{1}{4}$ an inch long, but there is a smaller proportion of abortive and otherwise

imperfect seed in a long leaf pine cone than in the cone of the loblolly pine. This would be decidedly to the advantage of the long leaf pine in seeding old fields, etc., were its seed not too heavy to be carried far by the wind. They usually fall within fifty feet of the parent tree, while the light winged seed of the loblolly have been known to scatter thickly over fields from trees over a quarter of a mile distant; and single seed are reported to have been blown several miles. Furthermore, as described more fully beyond, the seed of the long leaf pine are much more extensively destroyed by hogs, fowls, squirrels, rats, etc. Another reason for the exclusively loblolly growth in fields may be that even when the seed of the two pines fall on the same land the loblolly pine by its rapid growth during the first few years overshadows and effectually crowds out the more slowly growing long leaf pine; and the latter, during this early slow growth are easily destroyed by fires and by live stock. The two are, however, rarely seen associated together in second growth woods. The seed ripening in October, fall to the ground rapidly and if there is a warm moist season sprout immediately. In the event of a long warm rain just after the seed are matured, they will frequently sprout in the cones and the entire yield will be thus destroyed.

THE YOUNG PLANT.

The young long leaf pine seems to be specially adapted by the form of its root system for growing on a sandy soil. By the end of its first year's growth, its root system, which has grown rapidly, consists of a large tap-root which extends 6 to 10 inches deep in the sand

from the bottom of it branch out the smaller roots which draw nourishment from the soil. It is this deep seated root system, sent thus early far down into the soil, which enables this pine to grow on the sand barrens, and it is doubtless because the roots of the loblolly are small and divide for the first year or two into a great many small divisions, lying near the surface, that it does not get sufficient moisture and nourishment from the dry surface sand to enable it to thrive on the sand barrens before this land has been cultivated. This long tap root of the long leaf pine frequently goes through the sand into the loam soil and secures for the tree a firm anchorage against storms and enables it to draw its nourishment from a more fertile soil. The stem parts of the long leaf pine are as peculiarly adapted for growing on a sand soil as the root system is. Instead of the stem branching or growing the first year, it only puts out a great number of very long thick leaves, exceedingly close to the ground. These leaves soon spread out and help to shade the ground close to the plant and keep it moist. At the end of the first season's growth the single (terminal) bud is not over an inch and a half above the earth and the bud itself is nearly an inch long, so that it can be said that the stem of the seedling does not grow any in height during the first year, all the energy of the plant being diverted to increasing the root and producing the great tuft of long deep green leaves which spread out immediately below the bud and make the plant resemble more a tuft of some marvellous kind of grass than a young tree. Some of the lowest leaves usually die during the first year ; most of them remain on for two seasons.

The second and third year growth of the stem in height is slight, though it increases in thickness, but

after that, at least in a forest, its growth is wonderful. Frequently in a thick wood where young trees have been allowed to grow, they will in eight or nine years after height growth has begun, have reached a height of 18 or 20 feet and a diameter of no more than three or four inches, and will have grown each year from only one bud, the terminal one, at the end of the woody axis, there being no branches and no sign of any having been formed. For leaves there will be only a single broom like bunch terminating the slender stem. The rapidity with which this stem is raised and the fewness of its branches until the natural height of the tree is reached makes one of the fiine qualities of the timber. It gives long stocks which have no knots in them, even small ones, to produce any uniformity of quality or to make weak places on the interior of an apparently perfect piece of timber. This feature which is the cause of so fine a quality of wood is a great drawback to the development of the young trees. This single terminal bud is a very large and complicated structure, and when once destroyed in any way no other bud is usually ly formed by which the growth of the young seedling can be continued. It is true of most conifers (*i. e.* pines, firs, cypress and cedars) that they do not form buds readily and that they rarely sprout from the stump and are very difficult to reproduce from cuttings, etc., but with the long leaf such buds are formed and sprouts developed even more rarely than with most other conifers.

ENEMIES OF THE LONG LEAF PINE.

The long leaf pine has a severer struggle for existence than any other of our forest trees, for the reason

that in all stages of its reproduction and growth it is more severely and continuously attacked by a greater variety of enemies than any other. Besides the natural drawbacks to its development from the peculiar manner of forming several of its parts, and the fact that these parts when destroyed are not replaced, its large and sweet seed are eaten in large quantities by fowls of various kinds, rats, squirrels, and by swine, which prefer them to all other kinds of mast, and when there is enough long leaf pine mast become very fat on it. If the destruction caused by swine ceased here there would doubtless still be sufficient seed left to reproduce some parts of the forests as the mature trees are gradually thinned out, for one year old seedlings are common 12 months after heavy masts. No sooner, however, has the young pine gotten a foot high and its root an inch in diameter than the hog attacks it, this time eating the roots, which until two inches in diameter, are very tender, juicy, pleasantly flavored and free of resinous matter. In the loose sandy soil the piny woods hog or "rooter" finds little difficulty in following and devouring these tender roots to their smallest ends. Many small trees are destroyed in this way; and cattle, furthermore, are said to frequently bite off the tops of the small plants, and with it the terminal bud, in the early spring. This is doubtless done while grazing, more accidentally than otherwise.

Fires often destroy all the young pines that escape the hogs. They kill the small pines by burning the highly inflammable bracts around the bud and so stop its growth, or in high grass frequently burn all the leaves. Larger trees, even until they are three or four inches through, are easily killed in spring, when the sap is rising and the outer layer of wood is growing rap-

idly, by a hot fire which will burn the thin exfoliated layers of bark all over the trunk. The loblolly pine is less injured by fire because its bark is thicker and so offers more protection to the growing wood,—the bark, too, lying closer to the wood in firmly appressed layers, does not so easily take fire.

So far as has been observed, young long leaf pines are attacked by no injurious beetles or bark borers or by any fungi sufficiently to injure them. The mature pines, however, have in the past years several times been attacked by bark beetles in such numbers as to destroy the pines over large areas. A few trees which have been killed from their attacks can be seen at any time around the edges of districts when lumbering is in progress, or about districts which have been recently lumbered.

The chief agencies, then, which prevent a regrowth of the long leaf pine on the high sandy lands, are the hogs and the fires; and the attacks of the hogs are directed against parts which seem to have been developed to meet requirements of a plant growing on a dry barren soil of loose sand. These peculiarly developed parts are the seed, large for a pine, which contain abundant nutriment for the young plant to enable the root to push itself rapidly into the sand ; and then the long succulent root which grows for a considerable distance straight down without branching. Since the first settlement of these sandy lands the "ranging" of swine has been allowed in the forests, and while there were enough pines standing, and frequent masts, they fed a large number of hogs.

The practice of firing the barrens, has been adopted in many cases with a view to improve the pasturage ; while in many other cases, after the trees were boxed,

the leaves and trash pulled away from around them, the forests were burned over to prevent, in a dry season, a chance conflagration getting from under control and burning the faces of the turpentine boxes and the timber. That this policy of burning the barrens is a very bad one and calculated to do far greater damage than that immediately apparent has perhaps been made evident. That sooner or later the present management or lack of management which has characterized all dealings with the barrens for the past 140 years, must be changed if the long leaf pine forests are to be made self-propagating, no one who has ever seen their condition, or fully realizes what it is, can possibly doubt. The logical result of these burnings in the past has been the destruction of millions of feet of standing pine and the prevention of the growth of young trees; which, had they started even 50 years ago, would now be large enough for small timber and turpentine trees; while. the burnings of the present and future, if not soon discontinued, will mean the final extinction of the long leaf pine in this State.

NITRIFICATION.

J. R. HARRIS.

The changes which nitrogenous organic matter, or any form of nitrogen, undergo in nature in being converted to nitric acid, or nitrates, is called nitrification. Nitrogen is one of the most abundant, and at the same time most important, elements in nature. More than

three-fourths of the atmosphere around us consists of nitrogen, and it enters as an essential constituent into all forms of animal and plant life. The complex nitrogenous organic compounds found in nature are not assimilated as such, but are in some way formed within the plant from simpler nitrogen compounds taken in through the roots.

When these complex compounds are exposed to the decomposing agencies of the air and soil they readily return to the simpler and most stable forms which can exist in nature. The nitrates, as the last and highest state of oxidation of nitrogen, are known to be the most stable compounds. As an evidence of this, vast deposits of sodium nitrate have been stored up and preserved in the rainless regions of Chili, Peru and other countries, Minute amounts of nitrates are almost universally present in soils and waters. They have been found by many experiments and practical field tests to be the form of nitrogen most acceptable as a plant food and to an application of which they most readily respond. Nitrates would seem to have been indicated by nature as the most convenient starting point for the formation of all nitrogen compounds

A knowledge of their wide-spread existence in nature and the very important relation which they bear to agriculture has long been known. Chemists have performed many experiments and advanced numerous theories as to the manner of their formation. This natural phenomenon was evidently a process of oxidation brought about by means of atmospheric and soil agencies. Simple oxidation was not sufficient to explain the notable nitrate formation in compost heaps and nitre beds. The process was known to be much more active and to take place near the earth's surface. Calcium

carbonate or wood ashes were absolutely necessary and, contrary to all oxidation processes, a limited supply of air gave the best results. Carbonates evidently aided in some way, probably in decomposing the organic matter, but rapid decay hindered the process, and in combustion, which is more rapid oxidation, the production of nitrates was indeed very small. So that chemists puzzled over this apparently inexplicable question for a long time before a true suggestion was offered.

It is only within the past twenty years that a satisfactory theory has been advanced and only within the past three or four years, after the most careful and painstaking experiments by some of the most eminent physiological chemists has the theory been accepted.

A. Muller (Landw. Versuchs-Stat, 16, 273. Jour. Chem. Soc. 1873, 1267) observing the rapidity with which the ammonia of sewerage and certain waters changed to nitrates and that pure solutions of urea and ammonium compounds were not susceptible to this change, suggested that it was due to the action of ferments. The truth of Muller's suggestion was first shown by the labors of Schloesing and Muntz (Compt. Rend. 85, 1018). They studied the action of heat upon the process and soon found that varying temperatures exerted a remarkable influence. A temperature of 100°C. for one hour was sufficient to destroy the nitrifiable power of certain soils and vegetable moulds in which nitrification was known to be most actively taking place. The addition of a little unheated mould however, served to again start the process. This was very strong evidence that nitrification was in some way connected with organized life. A powerful microscope revealed to them the existence of numerous organisms of the most varied kinds, being most abundant in vegetable mould.

Nitrification could be started or stopped at pleasure and was clearly seen to be due to the life action of these micro-organisms. The observations of Schloesing and Muntz were soon followed by the publication of the experiments carried out in the Rothamsted laboratory by R. Warington (J. Chem. Soc. 1878, 44). In addition to confirming the previous experiments of Schloesing and Muntz, Warington added many proofs establishing the ferment theory and showing its relation to nitrification. The results of his experiments extending over a period of about fifteen years (J, Chem. Soc. 1878, 1884, 1885, 1889, 1891) are published with all the minute details. And it is to the labors of Warington more than to any one else that we owe our present knowledge of the nature and results of the life action of these microscopic organisms. The fact that they were really lower forms of life was not generally accepted, though the chain of evidence establishing this theory now seems to be complete. They possess all the attributes of organized life requiring a suitable temperature for their development and suitable food for their existence. The most favorable temperature is about 100° F; above 120° or below 40° they are rendered inactive, and are destroyed at 212°. The presence of organic matter and phosphates are essential. They are destroyed by the action of disinfectants, insecticides, and the presence of any considerable amount of alkalinity is detrimental to their growth, Just as calcium carbonate or wood ashes were required in nitre heaps so it, too, is necessary for the growth.

These organisms are found much more abundant in the surface layers of the soil, a fact which confirms observations, long known to be true, that production of nitrates was mainly confined to the surface. Even in

warm countries where the natives collect the nitrates accumulated as an incrustation on the soil, they are aware of the fact that the efficiency of the bed depends on removing only the upper crust. Warington found the following amounts of Nitrogen as nitrate in two fallow soils at Rothamsted:

In the first	nine inches	25.5,	40.1 lbs.
" " second	" "	5. 0,	14.3 "
" " third	" "	——	5.5. "

Portions taken at different depths were added to diluted, sterilized solutions of urine containing a little calcium carbonate and gypsum. The formation of nitrates was accepted as evidence of the presence of the organisms. In this way Warington succeeded in detecting their presence at depths of six feet from the surface, below this he was unable to find them. It is especially note-worthy that there was always a period of inactivity followed by a period of activity after the introduction of the soil portions. This he regarded as due to incubation, and the time required was much less in the case of surface portions. We would naturally expect to find any forms of life near the surface, and especially so, since the conditions most essential for their growth exist in greater abundace in surface soils. While Warington's cultures were made in solutions, in which the conditions were not the same as those of the soil, he was better able to control them, and to make the experiments of any desirable composition. But little is known of the way in which they act, only certain products are obtained as a result of the organisms' existence. When a suitable nitrifiable solution is seeded with either a portion of a nitrified solution or of a soil or soil infusion, nitrates are usually produced as the final result. In some cases notable quantities of ni-

trites were formed and they were noticed always to precede the formation of nitrates. This led Warington to suspect the presence of two different organisms. And various attempts were made to isolate them.

The Franklands (P. F. and Grace C.; Chem. News, March 21, 1890) were unable to isolate them by gelatin cultures. The organisms either did not grow on gelatin or, when so grown, lost the power of producing nitrates. They finally succeeded in getting an attenuation, one millionth of the original solution, by means of the dilution method, which produced nitrates in suitable solutions and had the microscopic appearance of bacilli. Warington (J. Chem. Soc. 1891, 484) finally succeeded in isolating the two organisms, the presence of which was indicated by his previous experiments. They are very similar in appearance and belong to the same family. The nitrous organism, isolated through successive cultures in ammoniacal solutions made permanently alkaline with sodium carbonate, and containing phosphates, oxidized ammonia to nitrous acid only; it produced nitrous acid in solution of milk, urine and asparagine, and could apparently assimilate carbon from acid carbonates. The nitric ferment did not produce either nitrites or nitrates from ammoniacal solutions, in fact ammonia hinders its action. It rapidly changes nitrites to nitrates.

Previous experiments of Warington (J. Chem. Soc. 1884, 637) had shown that in all experiments in which nitrogenous organic compounds were used, the formation of ammonia preceded that of nitrites and nitrates.

Warington believed that ammonia was the only nitrifiable substance, and only such substances as were capable of forming ammonia through the action of soil organisms could form nitrates. More recent investi-

gation has shown that the process takes place in at least three different stages, and is probably due to the action of different organisms. Emile Marchal (Bul. Acad. Belgique 1893 (3) 25, 727 abs. Chem. Cent. Blatt. 1894 2, 97) isolated some of the most prevalent soil organisms and studied their action upon organic matter. He was enabled to isolate by means of alkaline gelatin and peptone some thirty different species, all of which changed organic nitrogen into ammonia. Fifteen of the number were energetic in effecting this change. The Bacillus Nycoides, one of the most abundant in nature, produced ammonia from egg albumen, legumen and gluten. A temperature of about thirty degrees C. and a slight alkalinity was most favorable to its development. Messrs. A. Muntz and H. Coudon (Ann. Agron. 19, 1893 No. 5 page 209) found that Bacilli, Bacteria, Micro-cocci, and yeasts produced ammonia in sterilized soils from nitrogenous fertilizers. The production of ammonia then is not due to the action of any one species, but a great number of organisms have the power effecting this change. Ammonia once formed passes very rapidly into nitrates. This is shown by the facts that although these organisms are continually producing ammonia, yet only minute amounts of its compounds can be detected in soils. It is also formed in numerous other processes of putrefaction and decay, the greater portion of which escapes into the air to be again brought to the soil by snow, rain and dew. It is, however, generally admitted that plants may absorb some ammonia through the leaves, but the amounts obtained in this way are believed to be very small. When any considerable time has elapsed after a heavy application of ammonium compounds to the soil, only traces are found, whereas nitrates can be detected

in fairly large amounts. Nitrates are continually formed according to Berthelot and Andre (Storer, Vol. 1, pp. 307–8) in certain parts of plants. Here the plant cells promote oxidation in a manner analogous to that of the micro-organism. They prove this by inserting portions of the stems of the amaranth. plant into washed and sterilized soil. After a time a notable nitrate formation had taken place in the soil containing the plant stems, while none was found in other soils similarly treated but containing none of the amaranth. Small amounts of nitrates are formed from the action of electricity upon the nitrogen and oxygen of the air. Rain water collected immediately after a thunder storm invariably contains a greater percentage of nitrates than at other times. There are also various oxidation processes continually producing small quantities of nitrates. They can usually be detected in certain metallic oxides as ferric-oxide and manganese dioxide, though it has not yet been explained in what way these substances aid in the formation. The action of all these agencies is necessarily slow, and some nitrogen is lost to the soil, being given off in the free state. In other changes, too numerous to mention, great quantities of nitrogen yearly return to the air.

There must exist somewhere in nature a means of supplying this deficiency or the visible supply of available nitrogen would annually become less and less. The experiments of Lawes and Gilbert and Pugh in England and Boussingault in France, in which combined nitrogen was excluded by a series of wash bottles, were long ago accepted as proving that a plant could not utilize free nitrogen of the air. Recent investigations show that this is not true of leguminous plants when aided by the action of certain soil organisms. It is be-

lieved by some that the equilibrium between free and available nitrogen is in part preserved in this way. When leguminous plants are grown under normal conditions there are formed upon the roots small nodular or wart like protuberances varying in size from that of a pin head to a pea. They are generally called tubercles. Microbes are found associated with all tubercles, and are plainly the cause of their formation. Leguminous plants, when grown in sterilized soil, have no tubercles and require nitrogenous food for their growth. If soil infusions are added to the cultures in sterilized soil, tubercles are formed and the plants thrive without the addition of nitrogenous manures. It is then clearly not an inherent power of the plant, but depends upon the presence of the tubercles, which are caused by the soil organisms. Atwater and Woods (Conn. Station Ann. Report, 1889), found in a series of eighty nine experiments that, in all cases, where there was tubercular formations there was also an increased gain of nitrogen, being the greatest where there was the greatest number of tubercles. So far as our present knowledge extends root tubercles are confined to the Leguminosæ. They are readily produced on the roots of any member of this family, either by inoculation, the addition of small portions of crushed tubercles, or soil infusions containing the organisms. The concurrent opinion of all the investigators of this subject is that the formation of tubercles is caused by the soil microbes, and upon their formation depends the power of the plants to assimilate free nitrogen of the air. Here the agreement ceases. There are about as many different opinions in regard to the way in which this nitrogen accumulation takes place as there have been investigators of the subject. However it may be, it is

evidently a step in the process of nitrification, in that nitrogen is fixed in a form available to the plant. If, indeed, nitrates are neither produced by the organisms before this absorption takes place, nor within the plant by the action of the cells, it is certainly converted into a nitrifiable compound. It is only from a study of the results of the life action of these micro-organisms that the important role which they play in the many changes taking place in nature has been discovered.

THE EXHAUSTION OF THE COAL SUPPLY.

F. P. VENABLE.

Bodies of scientific men, as the British Association for the Advancement of Science, and various public prints have for some time been discussing the problem of the earth's coal supply and its probable exhaustion. There is a growing uneasiness on the part of the public that the end of our supply of coal is in sight and that we are in danger of running short of fuel. If the agitation of the question would correct the present enormous waste of fuel and lead to proper economy in its use, the gain would be great, The vast waste in coke ovens, the loss in crude furnaces, in imperfect engines and wretched heating appliances is enough to make any thoughtful man stand aghast. For instance, a high authority tells us that the loss in our heating stoves, grates etc., is 80 or 90 per cent, that is, one ton of coal should last us nine or ten times as long as it does now or do that much more work. A family now

using ten tons of coal for heating purposes during the winter could get along very nicely with one ton if the heating arrangements were perfected. Any one who has watched, on a still day, the long lines of smoke left by passing trains or the black trails stretching for miles behind ocean steamers can realize our prodigal waste of nature's generous gift. Still I do not think there is much reason for the dread that we are hastening to a time when the coal question will lead to a new struggle for existence, a painful illustration of the principle styled "the survival of the fittest." Many estimates of the coal supply and its probable rate of exhaustion have been given. These are based on very imperfect data and vary greatly but they all agree in giving us a respite of from one to two centuries. Taking these estimates as approximately correct and agreeing to the assumption that the use will increase at the rapid rate of the past quarter of a century, does not a greater danger threaten than the comparatively slight one of being forced to eat our food raw and winter in the tropics?

Geologists tell us that these coal deposits were laid away at a time when the proportion of carbon dioxide in the air was much greater than it is now. These masses of coal represent carbon dioxide decomposed and so made available by plant life and then stored away. We dig it up and burn it back to the original form, restoring the carbon dioxide to the air. These processes of decomposition and reoxidation go on side by side at present and Saussure has supposed a sort of equilibrium between the forces removing the carbon dioxide from the atmosphere, such as the growth of plants, the washing of rain etc., and those restoring it, as the breathing of animals, combustion of organic matter

and decay. That such an equilibrium exists is not above question. The changes in the amount of carbon dioxide would be so slight from year to year, however, and accurate analytical methods are so recent an acquisition that there is no experimental proof to settle the question. Still, it is clear that if the present proportion of carbon dioxide in the atmosphere is dependent upon a sort of equilibrium between, in the main, the formation of carbon dioxide by combustion and its removal by the growth of plants, this balance cannot be kept up if we enormously increase combustion, at the same time cutting down our forests and so limiting plant growth. The removal of this prejudicial body from the air by the formation of earthy carbonates is too slow to materially affect the result. This means then that the total amount of carbon dioxide in the air must increase and of course its ratio to the oxygen also. It is well known that this ratio does not bear much increase before the danger line is reached.

One of the calculations of the present total amount of carbon doxide in the air, or carbonic acid, as it is commonly called, places it at some four billion tons. Now taking one of the estimates (Mr. Wister's) of the consumption of coal for one hundred years, namely, 840,000,000,000 tons. we find this is equivalent to about 3,000 billion tons of carbon dioxide. This would give 30 billion tons a year, or seven and a half times the present estimate of the total amount in the air. This amount added to that breathed out by the increasing population of the earth makes it manifest that, before the huudred years are out, we will be in the serious danger of asphyxiation.

Though the above estimates may be somewhat beyond the mark, and, of course, they are offered as ap-

proximations only, one cannot help thinking that two of the great problems of the immediate future will be, devising less wasteful methods for using our fuel and freeing the air from the impurities we so recklessly pour into it.

As to the question of our supply of fuel, the great strides in the knowledge and use of electricity leave little doubt that it will furnish the light, heat and motive power of the future. We will not have to rely upon the etherific force of Keely or others. Every torrent, every waterfall, the motion of the tides, the quiet flow of the rivers, reservoirs of pent-up rainfall, all will be called into requisition to generate for us this force, so beneficent when tamed. Who would have believed a few years ago that it would so soon have attained its present position as motive and lighting power? It is already usurping the place of fuel in extracting the metals from their ores and we have scarcely entered upon the era of its use in the manufactures.

If, however, we must have fuel we need not seek very far for inventions which might supply our needs. It is not conceivable that we shall go on for another hundred years with the inconvenient and wasteful use of fuel in the solid form, any more than we would now be willing to return to the torch and tallow dip of our fathers as a source of light. Gaseous fuel will be the only form marketable in the next century and the sooner we come to this the better. The advantages in the use of gas for heating and industrial purposes have already been experienced by those dwelling in the natural gas region and they are loath to give it up.

The gaseous fuel of the future will consist mainly of hydrogen and carbon monoxide. The first we can easily obtain by decomposing water by means of electricity

and it is only a question of cost that interferes with its present use. The second constituent, carbon monoxide, can be prepared by the same agency from the carbon dioxide or carbonic acid, of which we have been speaking and, if the demand justified it, the methods of production for both of these substances could doubtless be so improved and cheapened as to become entirely practicable.

We must bear in mind that there is no destruction of matter possible on the face of the globe, and our use of the coal means only that we change it into some not immediately useful form from which, as we have just seen, it is possible to recover it, thus bringing it into use again. In this we would be but imitating nature in her cycle of changes. Man dies, his body decays and its constituent materials come into general circulation once more and are ready to be utilized in the building up of a new man. Men burn a plant, some living growing plant somewhere gathers together the materials thus once used and scattered, and gets them into a shape in which man can use them again.

We have not taken into account the possibility, as shown by repeated experiments, of utilizing the sun's heat and the immense amount of energy scattered by it over the earth's surface. We are told that the total amount of this energy poured out every year upon each acre of the earth's surface is some 800,000 horse-power. As Crookes says, what a waste is here! A flourishing crop grown upon that acre utilizes only some 3,200 horse-power and consequently 786,800 horse-power is lost.

Even a small part of this caught, concentrated, set to work, changed into electricity or stored up against a rainy day when clouds come between us and our

source of energy, would suffice for all man's present needs.

Of course, the coming of a time when water-power and sunshine will be the force-giving, and hence wealth producing conditions, will work many changes among the nations and the advice given by some to such countries as England, which can hope for but little under these new conditions, to pay off their national debts and so relieve posterity from all possible burdens, is not without just foundation.

The outlook is, therefore, not so bad as it seems at first sight and we may get along very comfortably, long after our supplies of natural gas, petroleum, and coal have been exhausted. Still economy should be insisted upon and these grand gifts of nature not squandered.

SULPHUR FROM PYRITE IN NATURE'S LABORATORY.

COLLIER COBB.

An interesting occurrence of native sulphur in York county, South Carolina, came to my notice in connection with the work of the University Summer School of Geology, at King's Mountain, in the summer of 1893, and having visited the place again with the class and made a careful examination in 1894, I deem the occurrence well worthy of note and record. Sulphur crystals have been described by G. H. Williams* from the

*Johns Hopkins Univ. Circular, No. 87, April, 1891.

Mountain View mine, Carroll county, Md., and Weed and Pirsson† have described the occurrence and form of crystals from the Yellowstone National Park; but so far as I am able to learn this peculiar occurrence is unique.

On the Greene place, opposite the home of Mr. E. B. McSwain, near the north-east corner of York county, and about two miles from the King's Mountain battle-field, South Carolina, is a well-marked vein consisting of two bands of iron pyrite about one inch in thickness, with a band of calcareous quartz, from one to three inches in thickness, lying between them. This is the condition of things in the unchanged portion of the vein. Following the vein to the northward and downward, we find the quartz honeycomed by the leeching out of the calcite, and later the interstices are filled with native sulphur, that portion of the pyrite lying next the quartz having been changed to iron oxide. I was unable to find any dikes in the immediate neighborhood, and though the vein was in a portion of its course folded with the schists composing the country-rock, the folded portions were in most instances entirely unchanged.

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†Am. Jour. Sci., xlii, 401, 1871.